



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

Langley

REPLY TO  
ATTN OF: GP

APR. 9, 1974

TO: KSI/Scientific & Technical Information Division  
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General  
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,797,098

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) :  

NASA Patent Case No. : LAZ-10,941-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES

NO

APR 1974

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Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Figure No. 1 of the Specification, following the words "...with respect to an invention of..."

*Bonnie L. Woerner*

Bonnie L. Woerner  
Enclosure

**United States Patent** [19]  
**Bement**

[11] **3,797,098**  
[45] **Mar. 19, 1974**

[54] **TOTALLY CONFINED EXPLOSIVE  
WELDING**

[75] Inventor: **Laurence J. Bement, Newport News,  
Va.**

[73] Assignee: **The United States of America as  
represented by the National  
Aeronautics and Space  
Administration, Washington, D.C.**

[22] Filed: **Sept. 14, 1972**

[21] Appl. No.: **289,048**

[52] U.S. Cl. .... **29/470.1**

[51] Int. Cl. .... **B23k 21/00**

[58] Field of Search.... **29/421 E, 470.1, 486, 497.5**

[56] **References Cited**

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Primary Examiner—J. Spencer Overholser

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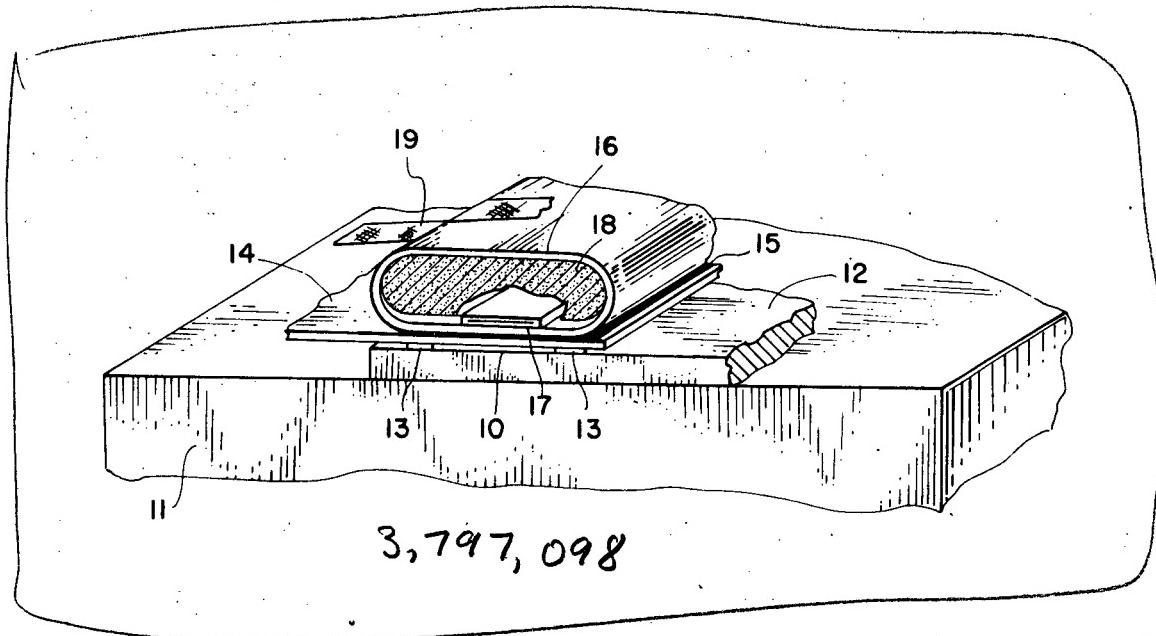
Attorney, Agent, or Firm—Howard J. Osborn et al.

[57]

**ABSTRACT**

A simple means for eliminating the noise and debris of explosive welding techniques by totally enclosing and applying the explosive pressure through the wall of the enclosure.

**5 Claims, 4 Drawing Figures**



(NASA-Case-LAR-10941-1) TOTALLY CONFINED  
EXPLOSIVE WELDING Patent (NASA) 5 p  
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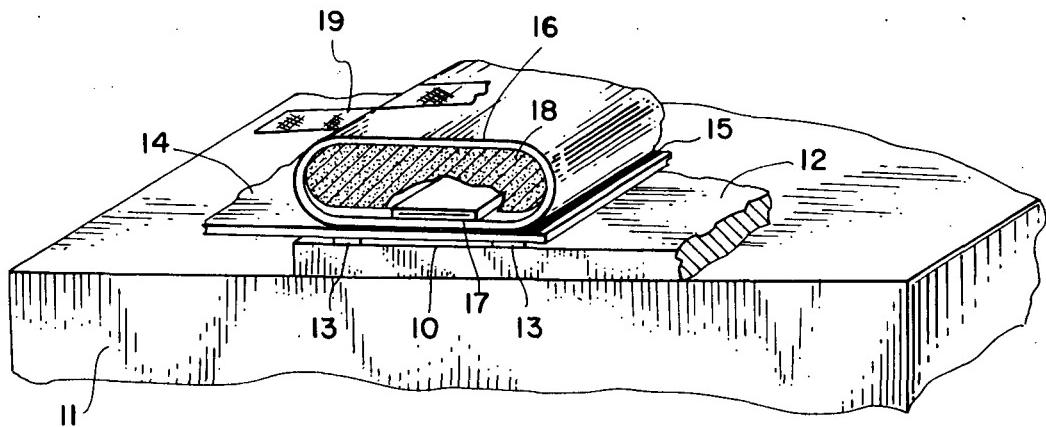


FIG. 1

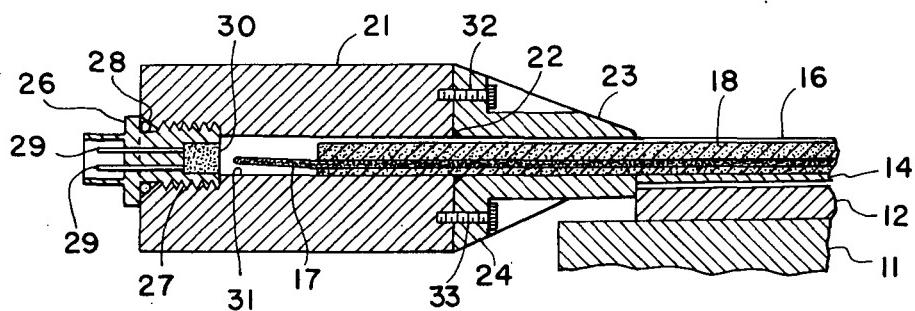


FIG. 2

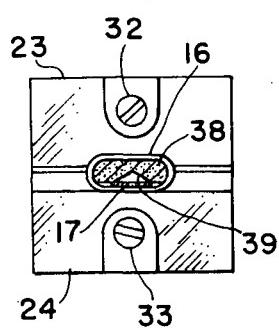


FIG. 3

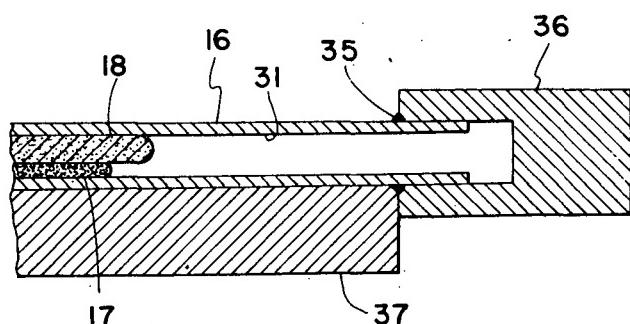


FIG. 4

**TOTALLY CONFINED EXPLOSIVE WELDING****ORIGIN OF THE INVENTION**

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for Governmental purposes without the payment of any royalties thereon or therefor.

**BACKGROUND OF THE INVENTION**

This invention relates generally to explosive welding techniques and specifically to a means of limiting the noise and products of the explosive process.

Explosive welding as presently practiced is an efficient method for bonding materials which are difficult to weld by more conventional means. It is particularly useful for thin materials which might suffer damage or change properties due to heat; for specific materials such as titanium or aluminum which have unique properties requiring a high degree of skill for conventional welds; and for large structures which require complex and expensive equipment to obtain uniform welds by conventional means.

Explosive welding is a comparatively simple procedure with which such materials may be bonded by relatively unskilled personnel. In such a technique the parts to be welded are spaced slightly apart by separators, jigs, or dimples and explosive is attached to one of the parts directly opposite the proposed bond area. The other part to be welded is rigidly supported on an anvil or table. Upon detonation of the explosive the parts to be welded are driven together with such force that they are metallurgically bonded. It is generally accepted that as the collision occurs remaining surface contaminants are stripped away, providing virgin metal for the metallurgical bond.

The tooling requirements for such an operation are very minimal. Satisfactory seam welds can be secured with only a cord-like preformed explosive, aluminum spacers, clamps, masking tape and a commercially available blasting cap detonator. The fabrication designer is able to specify all these items so that an unskilled person can perform the operation with reasonable certainty that a leak-proof bond will result. Because of the minimal tooling, low cost, and ability to weld aluminum and titanium, application of the explosive welding technique is anticipated in the aircraft industry and in extra-terrestrial applications. It is viewed as particularly applicable to the fabrication of space stations in orbit. Despite its advantages and the fact that the technique has been under development for almost twenty years, it has seen relatively little industrial use.

This may be because of the psychological effects of the noise and scattering of debris from the explosion. While such phenomena are relatively minor when a small amount of explosive is used, they do present some safety hazard and create a reluctance to the use of this otherwise valuable technique. This same explosive debris presents another problem in some applications. In high vacuum, space and other applications which require close control of potential contaminants, the explosive welding technique presents the problem of scattering debris into areas where it causes undesirable contamination. The present invention solves these

problems without adding significantly to the complexity or cost of the basic technique.

**SUMMARY OF THE INVENTION**

The present invention is a method and associated apparatus for confining the undesirable byproducts and limiting the noise of explosive welding, the use of which has been limited because of such phenomena. The apparatus is comprised of a simple enclosure into which the explosive is placed and within which the explosive is placed, and within which the explosion occurs. Due to the shape of the enclosure, the placement of the explosive within it, and the manner in which the enclosure is placed upon the material to be welded, the force of the explosion is transmitted to the proposed bond area. Moreover, since the explosion is totally confined within the enclosure the noise of the explosion is reduced dramatically and no debris is strewn about to contaminate the weld area or create personnel hazards.

In one example of a seam bonded by explosive welding, flattened steel tubing is used as an enclosure. This is attached to the weld material by the use of masking tape, just as the explosive itself is attached in unconfined explosive welding. The preformed explosive is slipped into the tubing along with a strip of silicone rubber which holds the explosive against the flattened side of the tubing which is adjacent to the proposed weld area. The explosion is initiated electrically by a commercially available detonator which threads into a fitting welded to one end of the tubing. The noise generated is no more than the rattle of metal, whereas an unconfined explosion creates noise comparable to that of a very close shotgun firing. The residue from unconfined explosive welding contains carbon, portions of the explosive sheathing material, and masking tape. Such residue is completely contained when the confined technique is used so that the use of such a bonding method becomes practical even in the restricted environment of a space station.

The method of confined explosive bonding retains all the benefits of the original technique. It is capable of welding methods that are normally extremely difficult; it can weld very thin materials such as those used on aircraft and spacecraft; it requires very little tooling so that it may be used in remote installations by unskilled labor. Because of these original benefits, the totally confined explosive welding method eliminates the major remaining problems involved in the process, those of noise and debris, with no significant sacrifice of simplicity.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a perspective view of the apparatus for confining the explosive showing a typical cross section;

FIG. 2 is an axial cross-sectional view of the detonator adapter assembly;

FIG. 3 is an end view of the detonator adapter assembly; and

FIG. 4 is an axial cross-sectional view of the closed end fitting.

**DETAILED DESCRIPTION OF THE INVENTION**

The embodiment of the invention selected for illustration as shown in FIGS. 1 and 2 is one used for seam welding. FIG. 1 shows a typical cross-sectional view perpendicular to the planes of sheet materials 12 and 14 to be welded and to the centerline of the proposed

bond area 10 at which they will be joined. Upper sheet 14 is 0.040 inch thick aluminum; and while lower sheet 12 is 0.25 inch aluminum in this example, it should be understood that these materials may be either the same or different thicknesses. Lower sheet 12 is placed upon anvil 11 which supports the work, furnishes reactive force during the explosion, and absorbs excess shock waves. Separators 13 made of aluminum 0.010 inch thick, are placed on either side of proposed bond area 10 and are located with sufficient clearance so that they will not interfere with the subsequent bonding. Separation is required in the explosive welding process so that a velocity may be imparted to one or both of the pieces to be welded. This velocity is a basic requirement for the explosive welding process so that the collision between the workpieces strips the mating surfaces clean and metallurgically bonds them together. In the arrangement shown in FIG. 1, the velocity is imparted to upper sheet material 14 by the force generated by the detonation of explosive 17. This force is transmitted through the wall of the steel tubing of enclosure 16 and the silicone grease 15 which is placed between the lower flattened side of tubing 16 and the upper surface of the material to be bonded 14. Grease 15 is used to assure that no voids exist between tubing 16 and workpiece 14 and that the explosive pressure is efficiently transmitted to the material to be welded. Explosive 17 is completely contained within steel tubing 16 and its appropriate end fittings. This containment prevents any products of the explosion from reaching the surrounding environment and virtually eliminates the noise of the explosion. Enclosure 16 used in the arrangement shown in FIG. 1, is a steel tubing and may be formed from type 347 alloy. It is 0.85 inch on the longest dimension of its cross section and is 0.30 inch high. The wall thickness is 0.030 inch and the dimension of the flat surface is 0.5 inch. Enclosure 16 is attached to upper sheet 14 by the use of strips 19 of conventional masking tape.

Explosive 17 used in the specific embodiment shown is a linear ribbon constructed of lead sheathed RDX explosive. It is available with explosive loads of 7 to 25 grains per foot but in the specific example 15 grains per foot is used. Its size is 0.025 inch thick by 0.315 inch wide overall. It may safely be cut to length with a scissors. The use of an enclosure to contain the byproducts of the explosion and reduce noise is in no way limited to either the specific explosive or the specific enclosure described herein. However, it should be understood that the enclosure must be selected to contain the explosion without rupture while the explosive should be selected with consideration of materials and thicknesses to be welded.

The silicone filler strip 18 is slipped into steel tubing 16 along the explosive 17. Together they are sized to form a snug but not tight fit within tubing 16. Filler strip 18 holds explosive 17 in contact with the flattened side of steel tubing 16 during preparation. When the explosion occurs filler strip 18 attenuates and diffuses that force which is directed away from weld area 10 so that no rupture occurs in the topside of tubing 16. The silicone rubber filler strip 18 also contributes to the reduction of the noise from the operation.

FIGS. 2 and 3 illustrate the detonator adapter assembly which is used in conjunction with the configuration of FIG. 1 to accomplish total enclosure of the explosive. Because of the shock pressures generated by the

explosion such fittings must be structurally strong and contain pressure seals at all joints. This is accomplished in the illustrated assembly by attaching steel enclosure tube 16 to steel end housing 21 at weld joint 22 by welding prior to setting up the explosive welding operation. The commercially available detonator cartridge 26 is screwed into end housing 21 by means of threads 27 and tightened against O-ring 28 to complete the pressure seal to the interior of the explosive enclosure extension 31 drilled into the center of housing 21.

The aluminum restraining adapters 23 and 24 are added to the assembly to prevent the explosive shock from fracturing enclosure tube 16 at weld joint 22. The explosion is initiated by supplying current to electrical pins 29 which detonates charge 30, in turn detonating explosive 17. The explosive detonates along its length at a finite velocity of the order of 26,000 ft/sec. As this detonation wave passes weld joint 22 between end housing 21 and tubing 16 the stress created by the shock wave on the unsupported tubing would be such as to rupture the tubing at the weld. Upper restraining adapter 23 is attached to end housing 21 by bolt 32, while lower restraining adapter 24 is attached to end housing 21 by bolt 33. Together the restraining adapters 23 and 24 completely surround tubing 16 and support it in all directions. This support decreases as the distance from the end housing increases because of the tapered construction of the restraining adapters. Upper restraining adapter 23 provides restraint which at end housing 21 approaches the same degree of restraint afforded by the end housing while at the other end the adapter is tapered to approach the strength of only the unsupported tubing 16. Lower restraining adapter 24 furnishes restraint approaching that of the end housing at one end, but is tapered such that at the other end it approximates the restraint provided to tubing 16 by the work piece 14. The surface of the tubing 16 against which explosive 17 acts, in this example the lower surface, must be supported in some manner for the entire length of the explosive in order to prevent a discontinuity at the work piece which would accentuate the stress on the tubing and cause rupture. The upper surface of the tubing does not require such backing since the shock from the explosive is damped by the silicone rubber filler material 18 and there is no backing material along the total tubing length.

FIG. 4 shows the closed end fitting used at the end of the tubing opposite from the detonator. It comprises a simple end cap 36 drilled to fit outside tubing 16. The tubing is inserted into cap 36 and welded at 35. Tubing 16 rests on support 37 for its length not supported by the weld pieces to meet the requirements for shock restraint. However, when tubing 16 is made long enough in the section that contains no explosive 17, the shock wave is reduced to a level that requires no support. Such a modification is valuable where the welding is done in confined quarters and it is desirable to place the end fitting elsewhere.

While the benefits of explosive welding are most apparent in long seam welding, neither the prior technique nor the invention described herein is limited to such a configuration. Any operation which previously used explosive welding can benefit from the enclosing of the explosive so as to limit the noise and debris. In spot-welding, as another example, small containers can be constructed which enclose the charge used for each spot.

Another variation of the technique prescribed by this invention is the use of two enclosures to contain the dual explosive charge used when a second charge is substituted for anvil 11 in the prior example. The confinement technique is also effective in its simplest form when no silicone grease as shown by 15 in FIG. 1 is used. In such an option only a slight loss of efficiency of transmission of explosive force may be experienced if the surfaces of tubing 16 and workpiece 14 do not mate exactly. The silicon rubber filler material 18 provides for other variations. In one case, it may be entirely removed and the absence of attenuation of the explosive force counteracted by strengthening the enclosure, shaping the enclosure, or minimizing the charge of explosive. The filler material may also be shaped and made of a material such that it will actually reflect the force back in the direction of the bond thereby increasing the force available from a given charge. Such a variation is shown in FIG. 3 in which filler material 38 has a triangular undercut 39. The enclosure may likewise be constructed so as to deflect the forces back to the work area to accomplish a similar increase in effective force.

It is to be understood that the forms of the invention herein shown are merely preferred embodiments. Various changes may be made in shape, size and the arrangement of parts; equivalent means may be substituted for those illustrated and described; and certain features may be used independently from other features without departing from the spirit and scope of the invention as defined in the following claims. For example, the enclosure shown is constructed from flattened steel tubing. Other shapes and materials may be used where the parts to be welded and the explosive used make them more effective or economical.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In bonding materials by explosive welding means wherein noise and debris from the explosion may cause disturbance to personnel or damage to property, the improved method which comprises:

totally enclosing the explosive material within a sealed enclosure to diminish noise and contain the products of the explosion;

attaching the enclosure to the material to be bonded; 45  
detonating the explosive material within the enclosure; and

accomplishing the bond by the application of explo-

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sive pressure to the bond area through the walls of the enclosure, said enclosure containing the explosion without rupture.

2. In the confined explosive welding method as in claim 1 filling the voids between the explosive enclosure and the material to be bonded with a substance which transmits the explosive pressure to the bonding area.

3. In the confined explosive welding method as in claim 1 filling the balance of the explosive enclosure with a material which attenuates and diffuses the explosive pressure which is not directed toward the bond area.

4. In the confined explosive welding method as in claim 1 filling the balance of the explosive enclosure with a shaped material which concentrates the explosive pressure upon the bond area.

5. In bonding material by explosive welding, an improved method of total confinement as in claim 1 whereby noise and debris are limited which is comprised of the steps of:

providing a complete enclosure of flattened steel tubing with end fittings which seal off the ends of the tubing;

inserting a ribbon-shaped explosive into the enclosure in such a manner that a flat side of the ribbon explosive rests against an inside flat wall of the enclosure;

inserting a resilient filler strip between the explosive ribbon and the opposite wall of the enclosure whereby the ribbon explosive is held firmly against the enclosure wall;

providing the materials to be bonded;

applying a void filling substance to one material to be bonded;

attaching the enclosure to the material to be bonded whereby the outer surface of the enclosure wall against which the explosive ribbon rests is held against the material to be bonded and compresses the void-filling substance;

detonating the explosive within the enclosure;

bonding the materials by application of explosive pressure to the bond area through the flat wall of the enclosure and the void-filling substance; and removing the unruptured enclosure from the bond area.

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